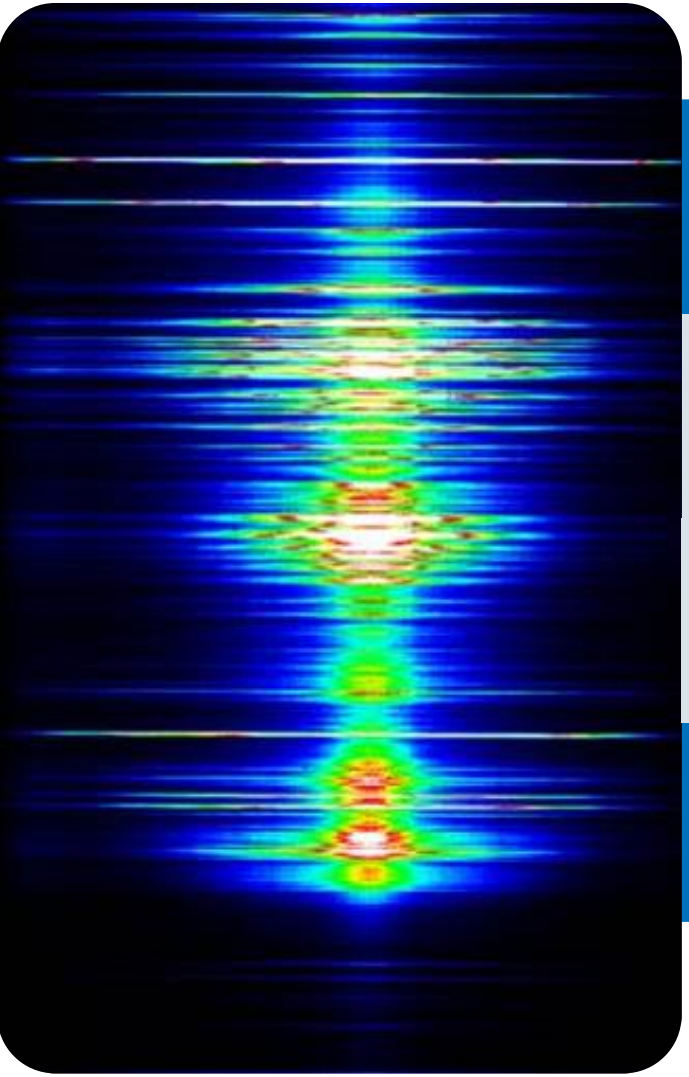


Spatial Resolved EUV Spectrum of EUV-Lamp

Solutions for Mask Metrology with Lab-Sources

Rainer Lebert[a], Thomas Missalla[a], Christoph Phiesel[a], Azadeh Farahzadi[a], Wolfgang Diete[a], Stefan Herbert[b], Serhiy Danylyuk[b]

a) Bruker ASC GmbH, Cologne, Germany
b) RWTH Aachen, TOS, Aachen, Germany
c) Fraunhofer ILT, Aachen, Germany

Lab based EUV (actinic) Metrology and Test

Many "actinic" tasks in the infrastructure of EUVL require Stand-Alone solutions:

Mask: reflectometry (ML & absorber; structures), scatterometry, defect inspection , actinic CD, Nanoscopy of patterns and defects …

Optics: Reflectometry, Scatterometry, Homogeneity, Interferometry, Contamination

Resist: Sensitivity, dose-contrast, LWR, Outgassing,

Components: Transmission, Absorption, Scatter, Chemistry, Nano- layers

EUV Lab sources are one key element

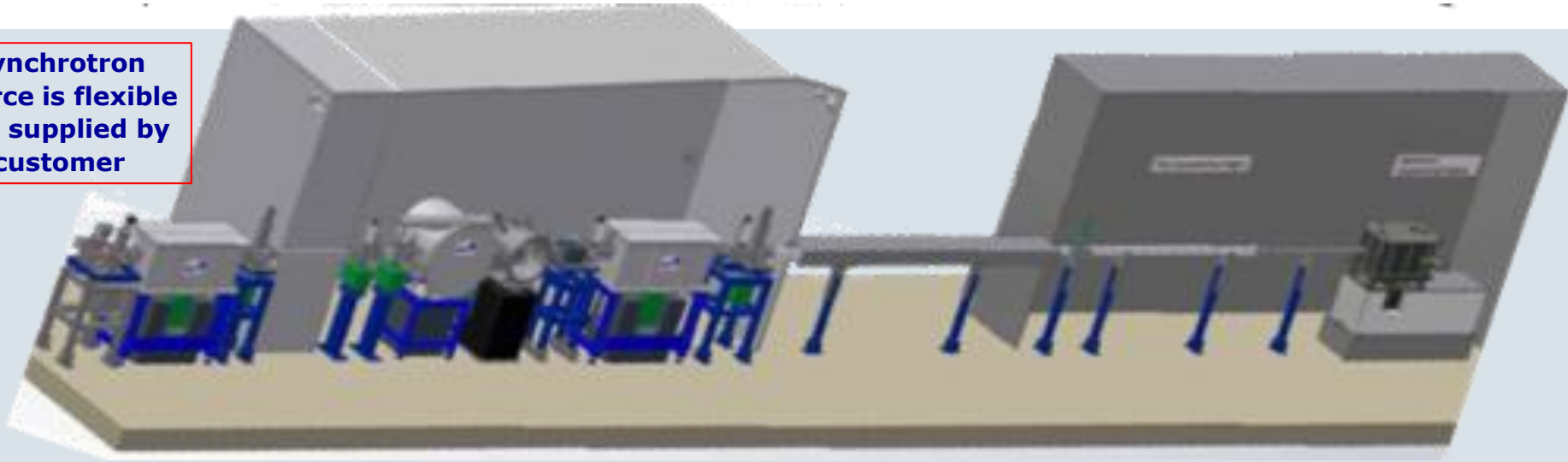
In contrast to HVM source, metrology sources are available in both general forms: DPP & LPP, which allows to select for the required features and can even be selected / tuned to special demands (Wavelength, bandwidth , spectral purity, Interaction area (sample), spatial distribution)

Any task:

Find effective solution of EUV-Source, collection, SPF, Optics scheme geometry, detection
+
High Quality (vacuum, cleanliness, vibration, safety, operation) tool integration.

Traditional Business Area: Synchrotron Instrumentation

Synchrotron source is flexible and supplied by customer

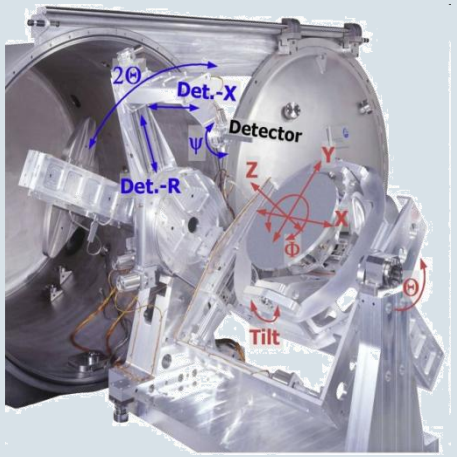


Collimating mirror | **DCM** | **QEXAFS DCM** | **Focusing mirror (toroid)** | **Microfocusing mirrors (KB's)**

We Design, manufacture qualify install and commission

Immanent Competencies:

- **Mechanical, electrical and optical design;**
- **Clean UHV; Stability (nano-rad)**
- **In vacuum nano-positioning,**
- **Cooling down to liquid N2 temperatures.**
- **Control Systems**



Here: one of a kind realizations or special adaptations are standard!

EUV & XUV Lab Source Portfolio

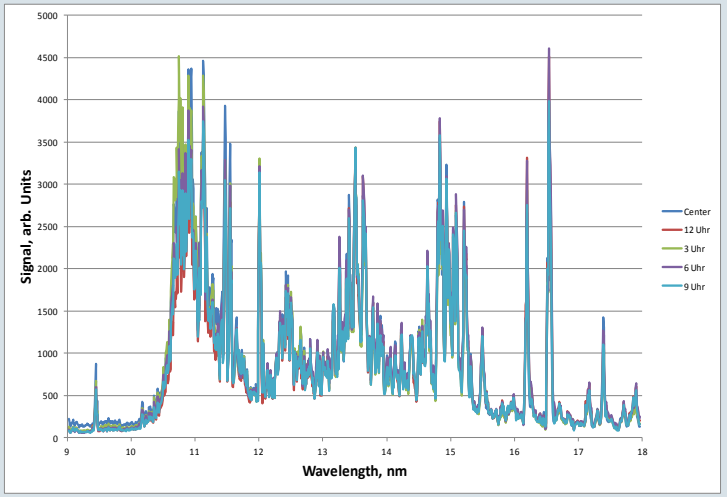
EUV metrology sources;

Demands: Power, Brightness, Debris-free, Stability, Cleanliness, Integration

Discharge Produced :

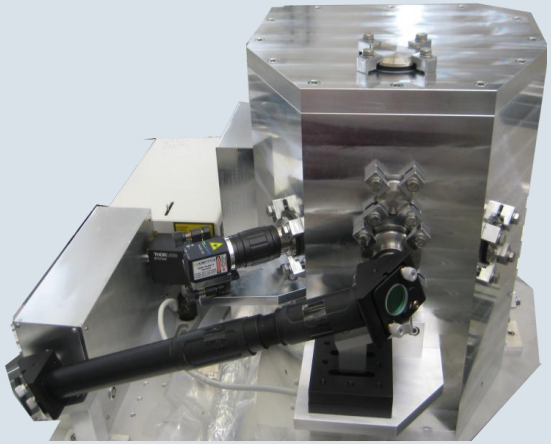
EUV-Lamp < 1 W EUV inband

EUV-Source > 20 W EUV inband



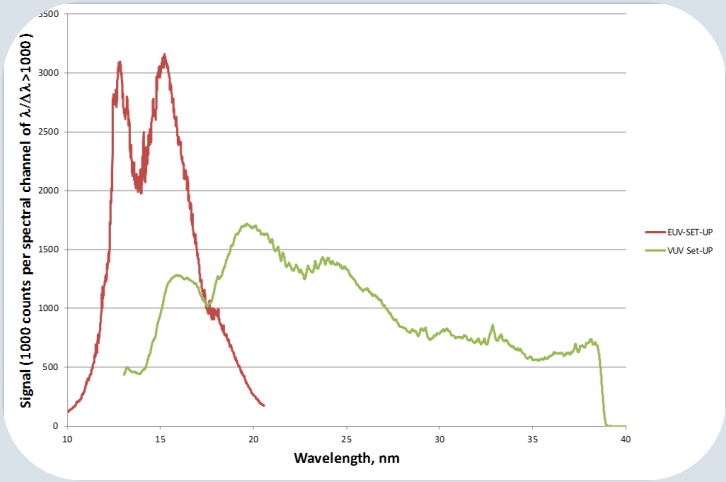
DPP spectrum of Xenon EUV-Lamp under different angles

Laser Produced :



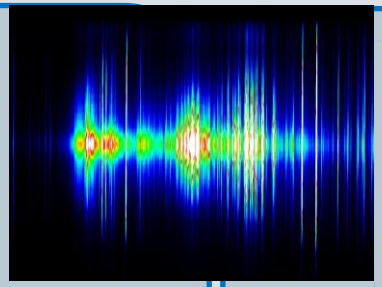
LPP <5 mW EUV inband for spectr.

PoC HB-LPP : 200 W/mm²/sr inband



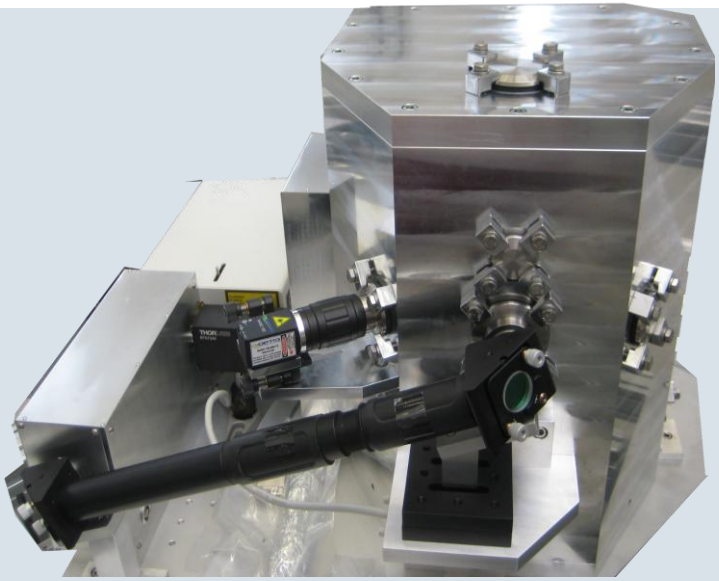
LPP source gold emission

DPP Source Systems 0.1 -40 W/(2 π sr) EUV inband



•EUV inband: 0.1 – 0.75 W/(2 π sr) • up to 1 sr collectable •< 500 µm FWHM source diameter	• EUV inband: 1 – 40 W/(2 π sr) • up to 1 sr collectable •< 500 µm FWHM source diameter

Low Power Gold LPP Source (< 5 mW /(2 π sr) EUV inband)



LPP < 5 mW EUV i.b. for spectroscopy

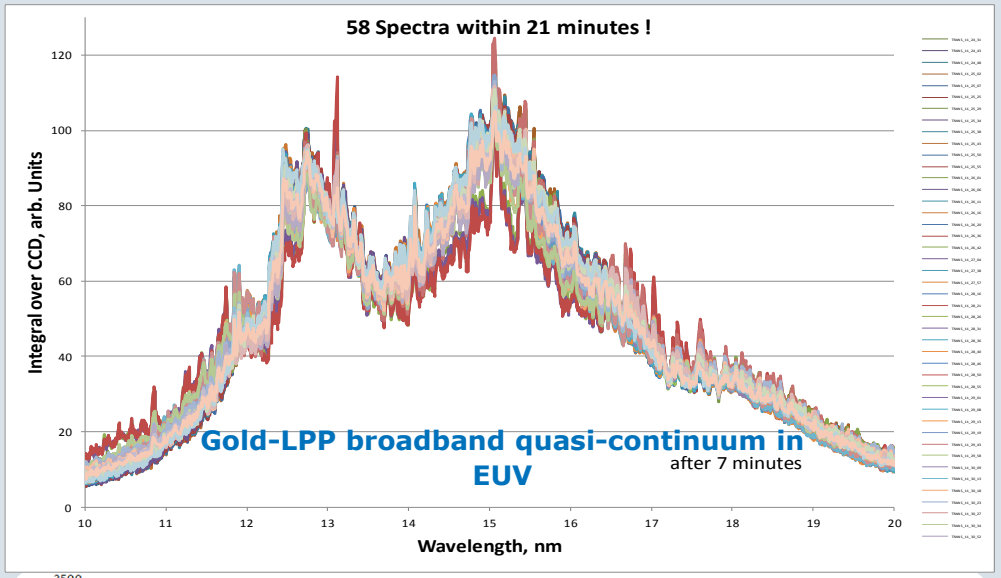
Special nearly continuous broadband spectrum for spectroscopy with gold target.

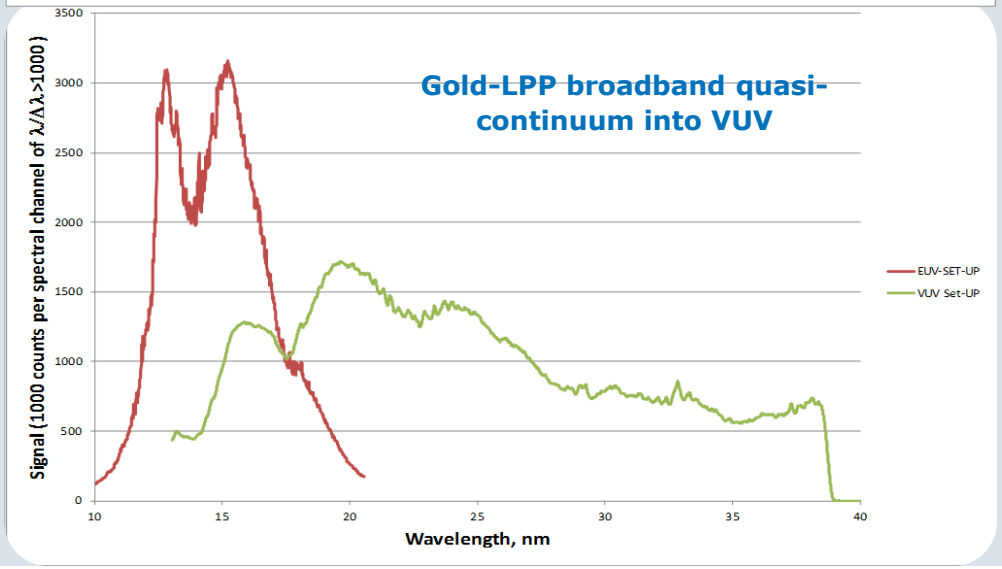
In close collaboration with Laser Institutes and established companies source solution is easily tuned for Demands; e.g.:

Powers of 5m - 5 W/(2 π sr)

inband EUV brightness of > 500 W/cm²/sr (for > 50 µm: Optimized source profile)

Source sizes down to < 20 µm





Integrated Solutions with the Lab Sources

EUV Mask Reflectometer

Task

Measure spectral reflectance curves on multilayer and absorbers with high precision and accuracy (x* SEMI specs for masks)

Demands on Source

Reliable and stable in daily use

Broadband EUV Spectrum

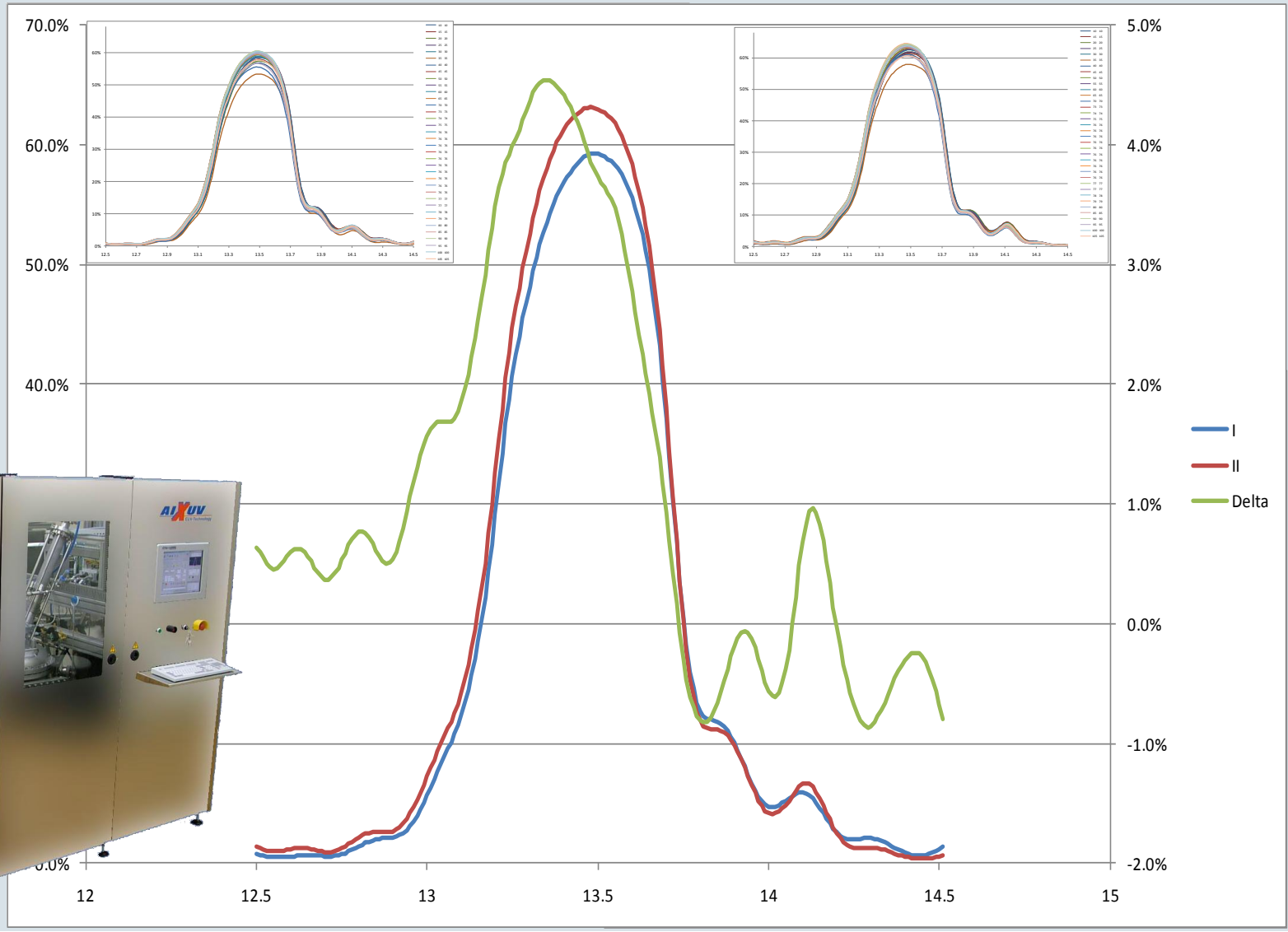
Medium power requirements

Concept & Source:

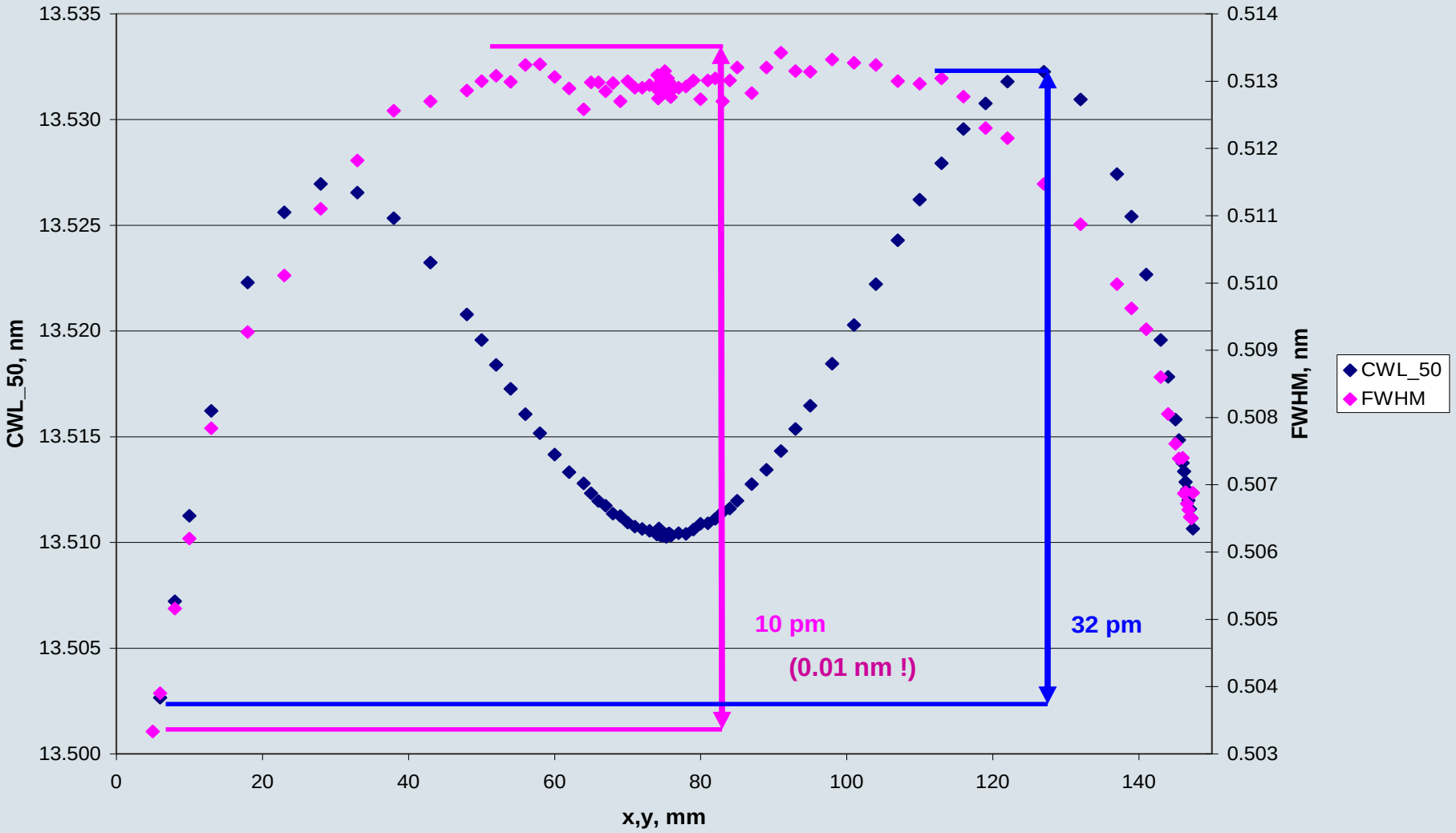
Polychromatic Reflectometry with EUV-Lamp

Feature	Reflectivity	CWL_50
Spot Size	e.g. 250*100 µm	
Time to measure	Typ. 20 seconds	
Precision (EUV ML)	≤ 0.2 %	≤ 1 pm
Accuracy(EUV ML)	≤0.5 %	< 5 pm

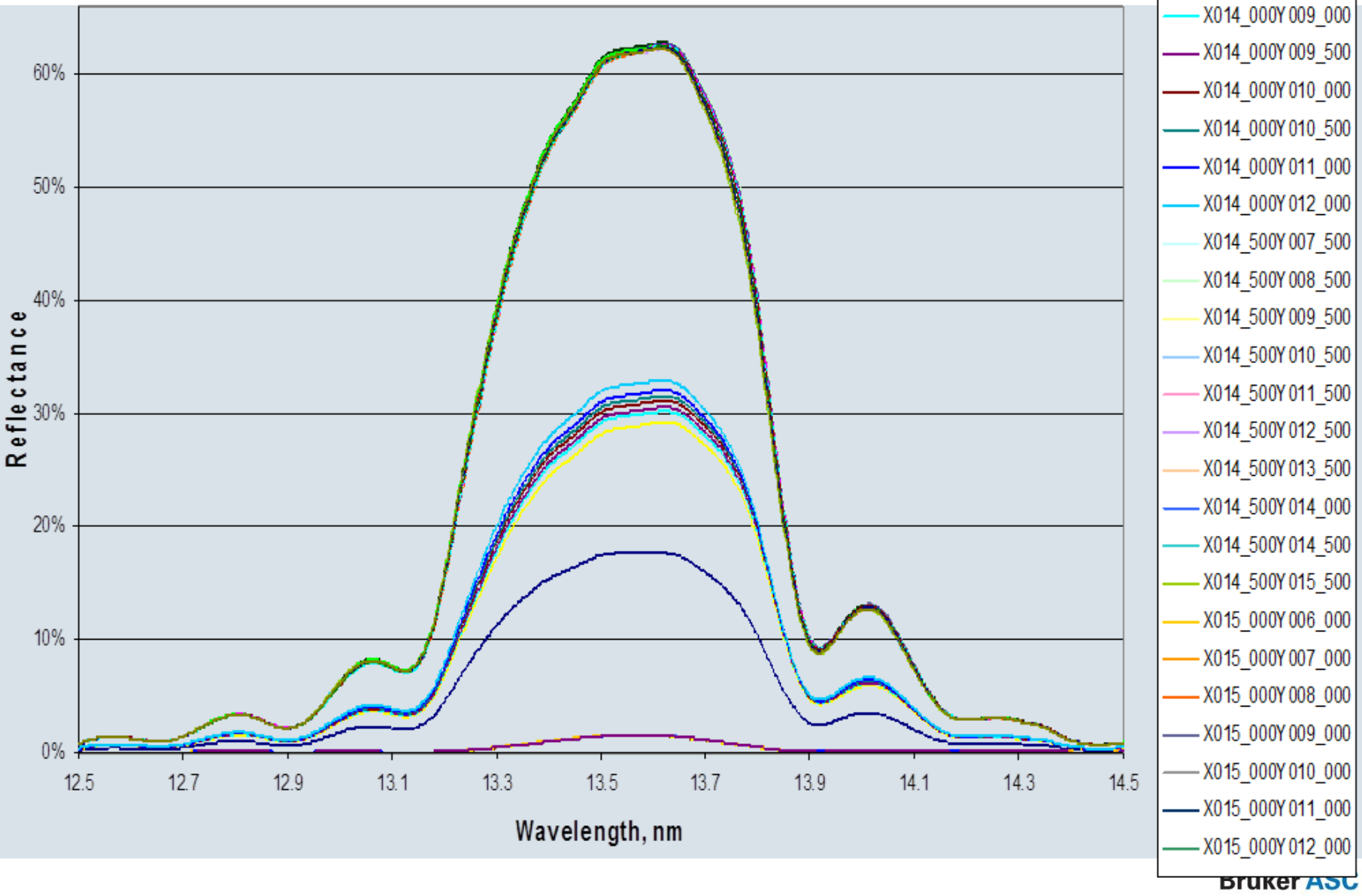
Example of application:
Characterize mask blank before or after cleaning



MBR Sensitivity: Diagonal Scan over Mask Blank



Stepping Measurement over structured mask delivers spectral information



EUV Mask Spectrophotometer

Task

Measure spectral properties of nearly arbitrary sample (ML, GI, Foils, Gases) in

8-20 or 12-40 nm

Demands:

Small spot ➔ ability to measure curved samples

Wide spectral range

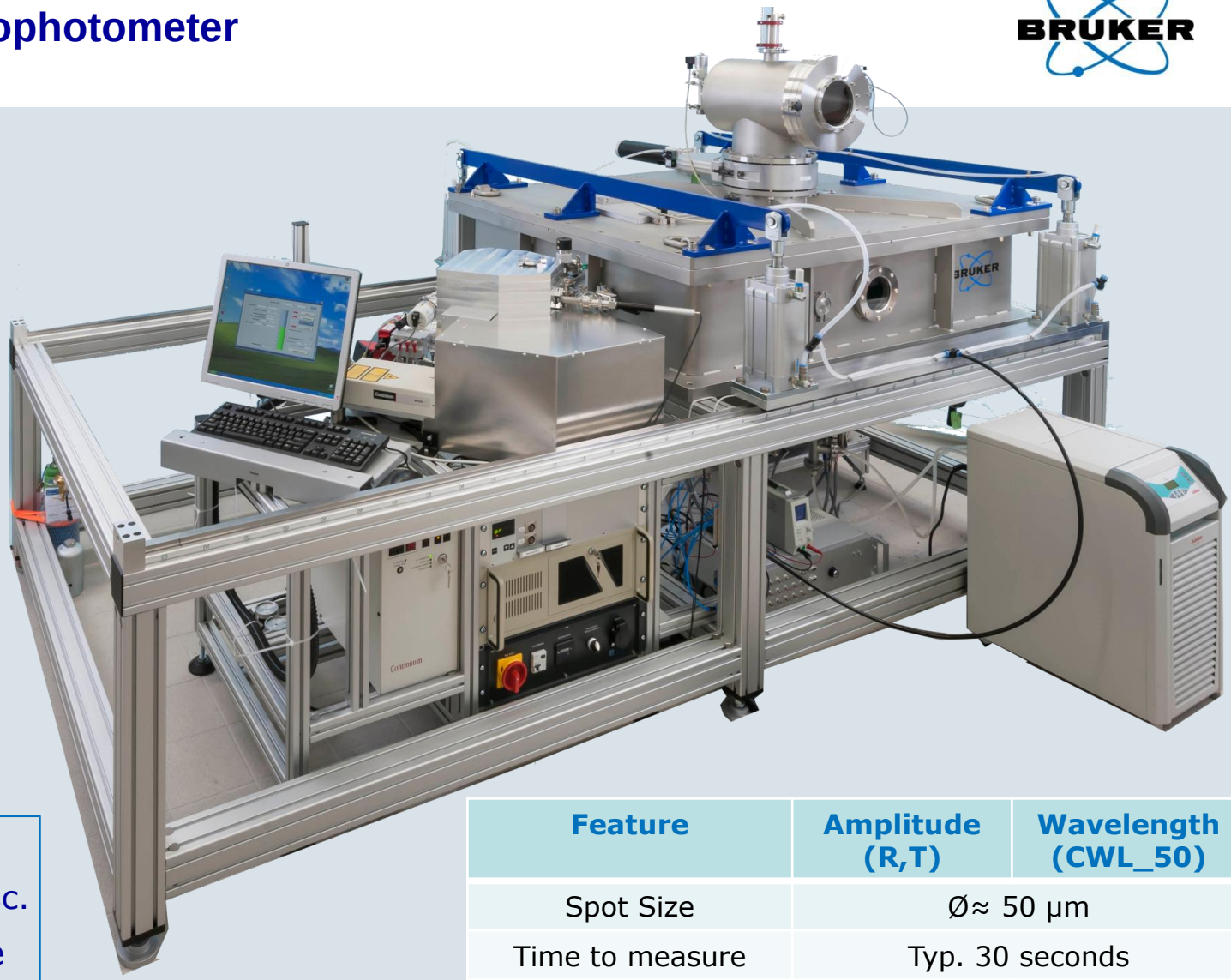
Wavelength accuracy

Concept & Source

Polychromatic Spectrosc.

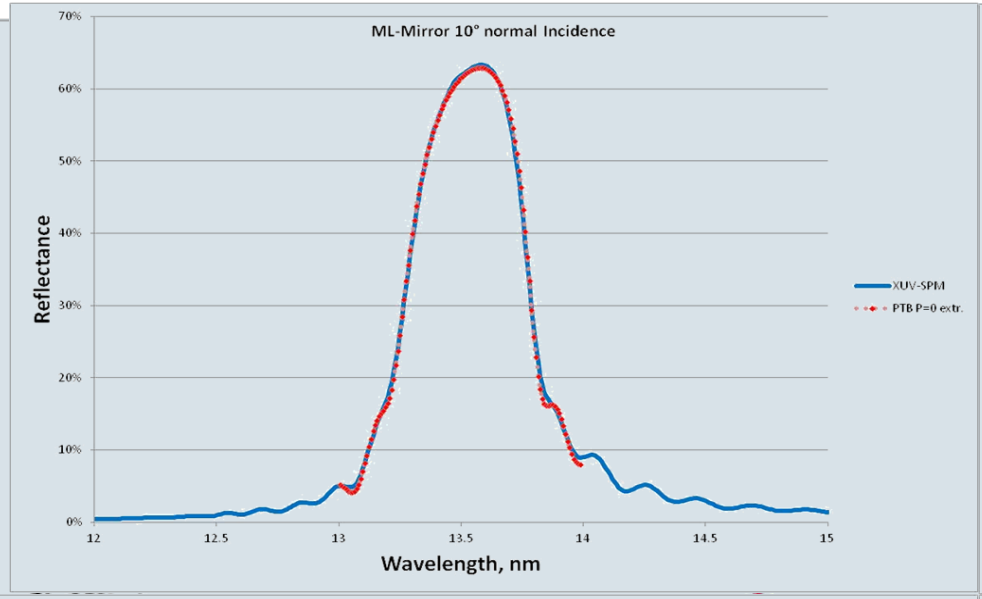
Small Gold LPP Source

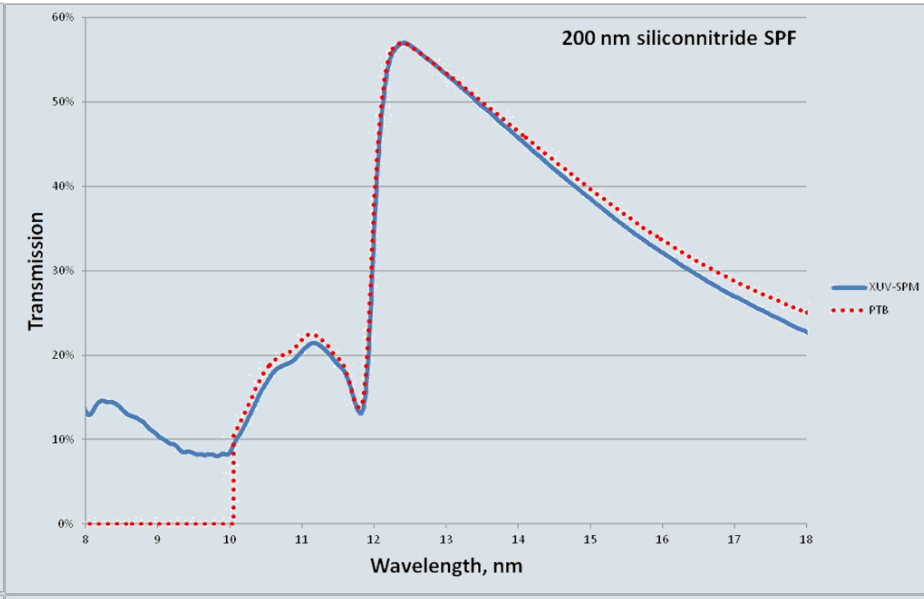
Imaged 1:2 imaged with toroidal mirror

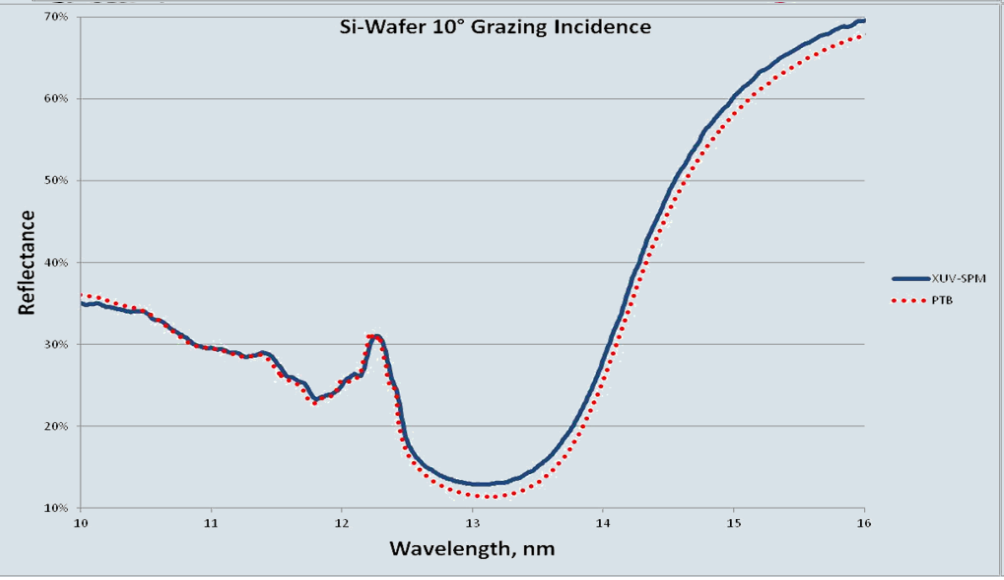


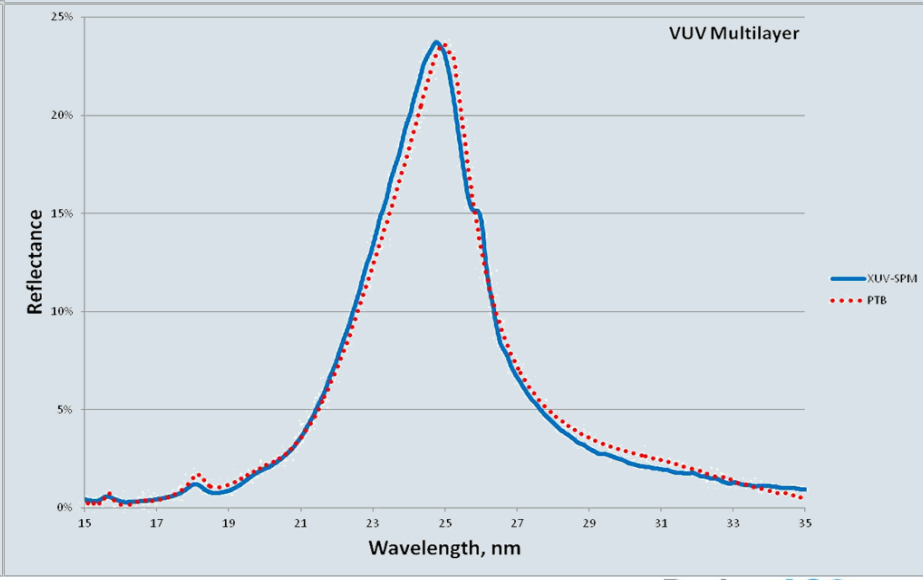
Feature	Amplitude (R,T)	Wavelength (CWL_50)
Spot Size	Ø≈ 50 µm	
Time to measure	Typ. 30 seconds	
Precision (EUV ML)	0.5 %	10 pm
Accuracy(EUV ML)	1 %	20 pm

XUV Spectrophotometer
GI & NI Reflection, transmission, VUV, Gases



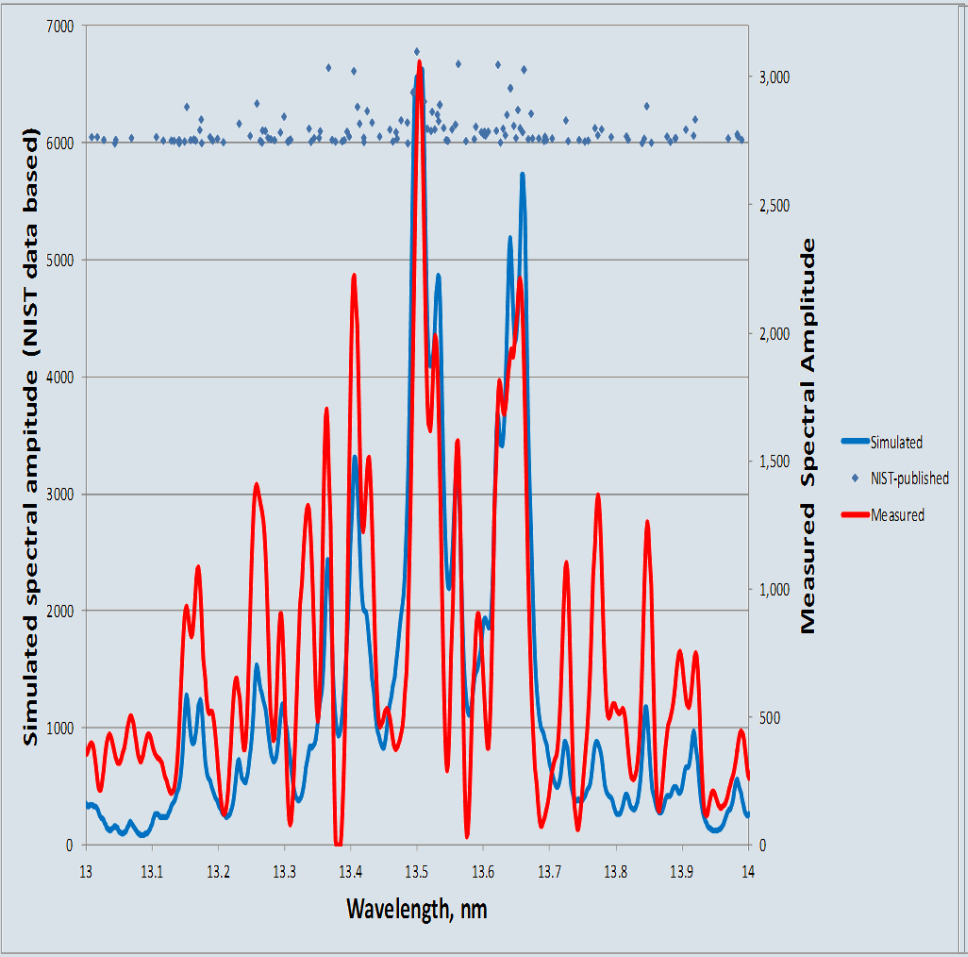




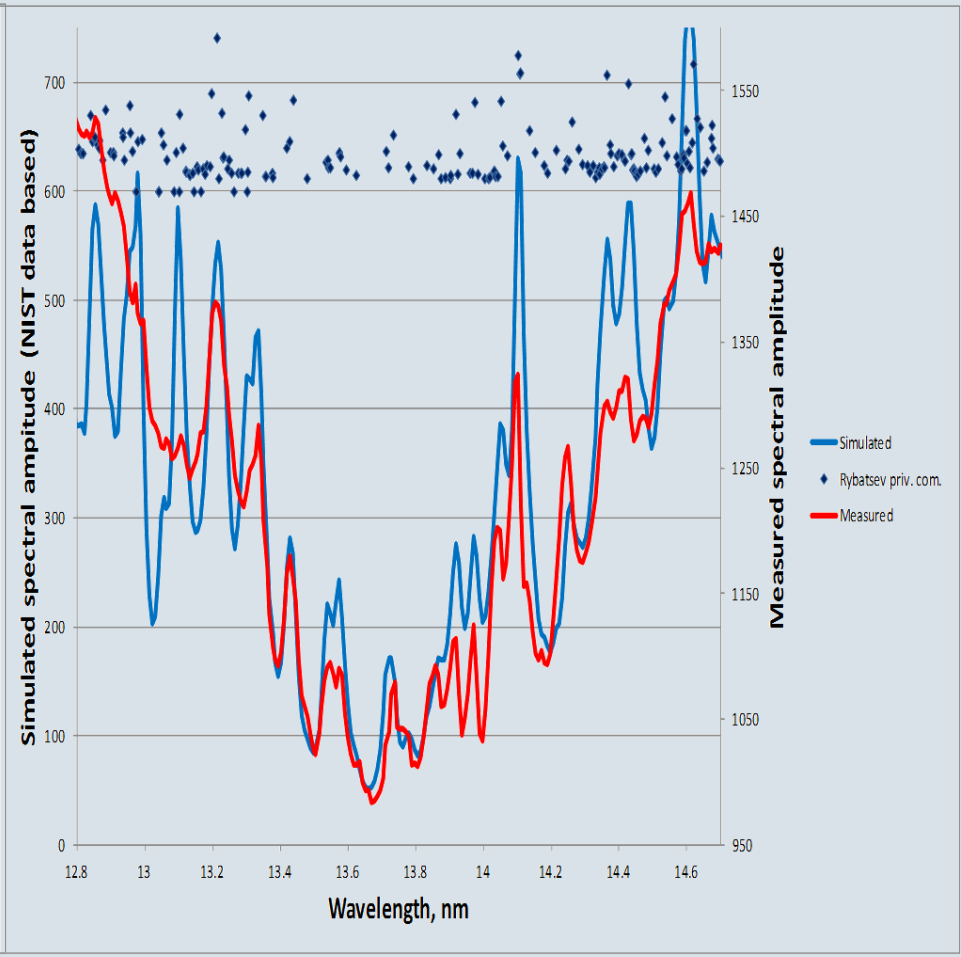


Immanent WL Calibration with by plasma lines

Xenon: MBR



Gold: SPM



➔Accuracy better one spectral channel

➔ MBR: < 1.6 nm; XUV-SPM < 8 nm @ 13.5 nm ($\lambda/\Delta\lambda$ >8,000 resp. 1,500)

Nanoscopy

Task

Microscope with sub-20 nm resolution;
Actinic Soft-X or EUV

Demands

Brightness (W/mm²/sr) and Throughput are correlated

Targets:
10, 50, 100, 500 W/mm²/sr

Concept and Source

DPP or LPP source

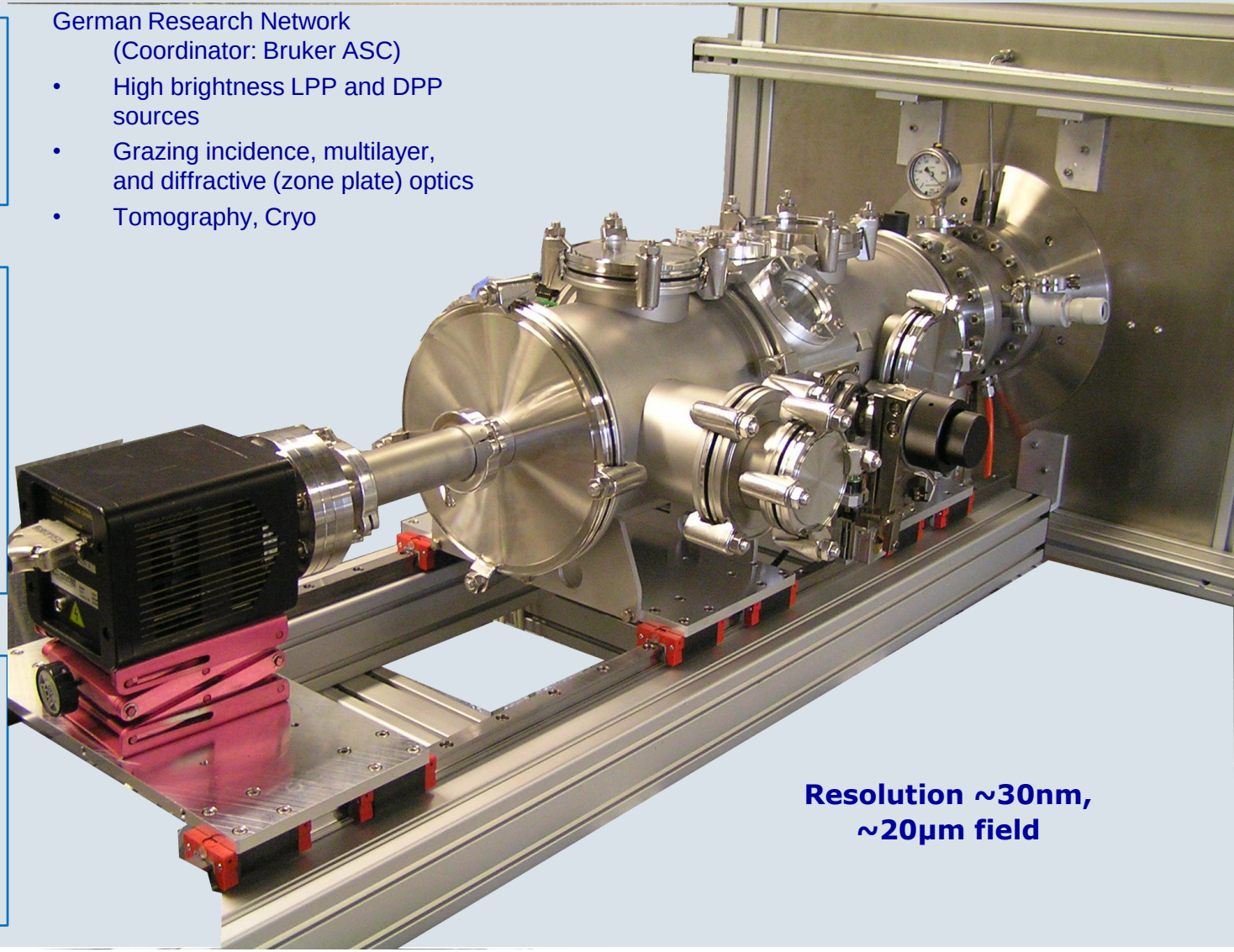
Single Line optimized

GI-Collector

Zone plate optics

German Research Network
(Coordinator: Bruker ASC)

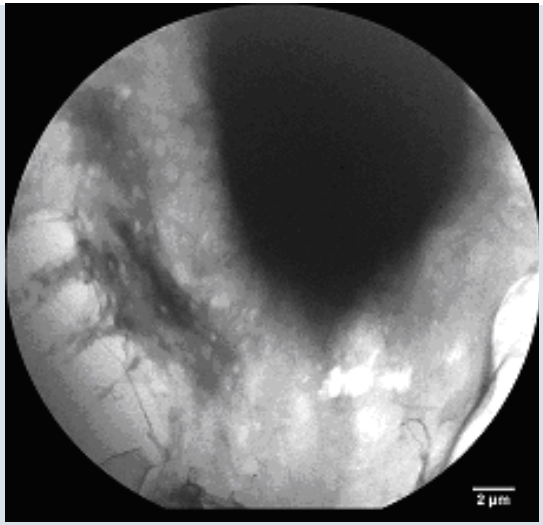
- High brightness LPP and DPP sources
- Grazing incidence, multilayer, and diffractive (zone plate) optics
- Tomography, Cryo

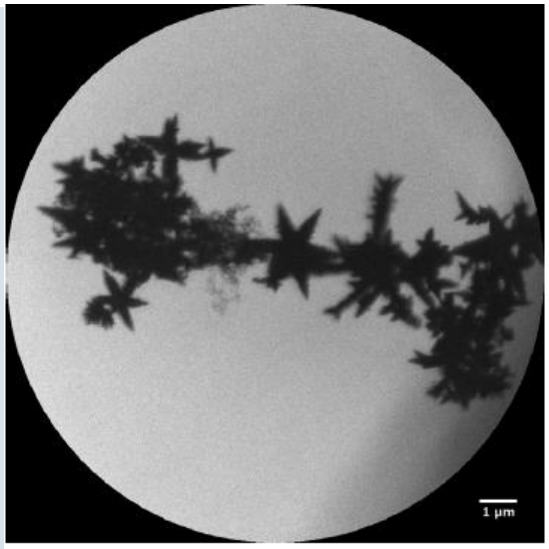


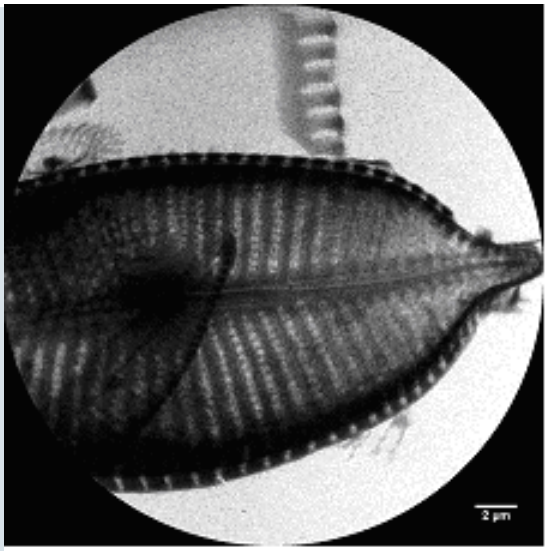
Resolution ~30nm, ~20µm field

M. Benk, K. Bergmann, D. Schäfer (2008)

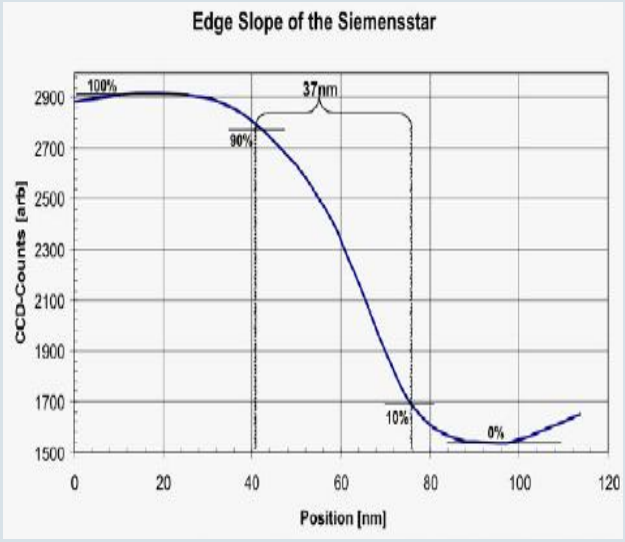
X-Ray Microscopy with DPP source:
40 nm Rayleigh Resolution demonstrated

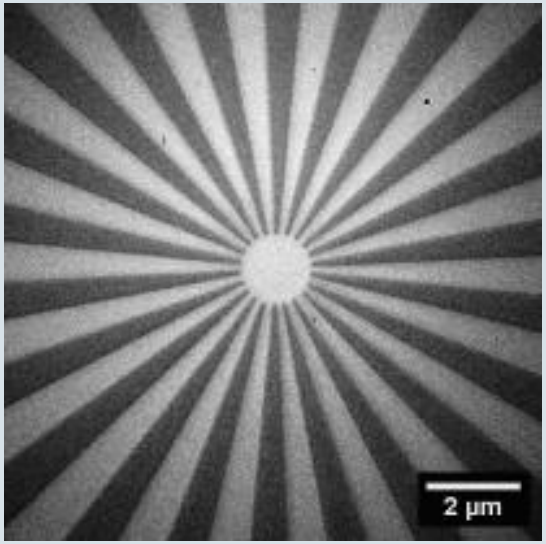


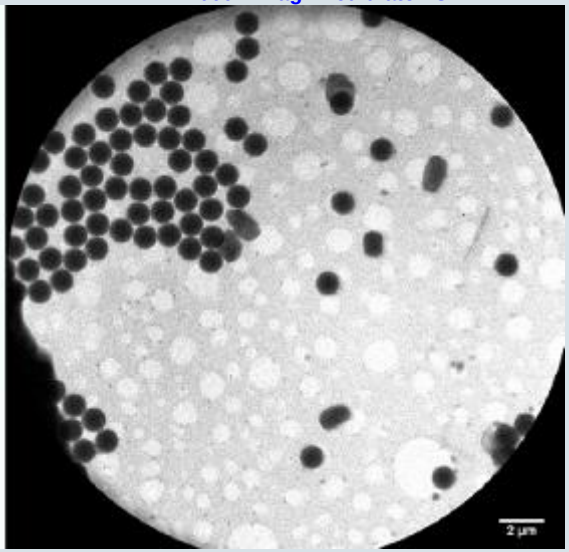




1000 x magnified diatoms







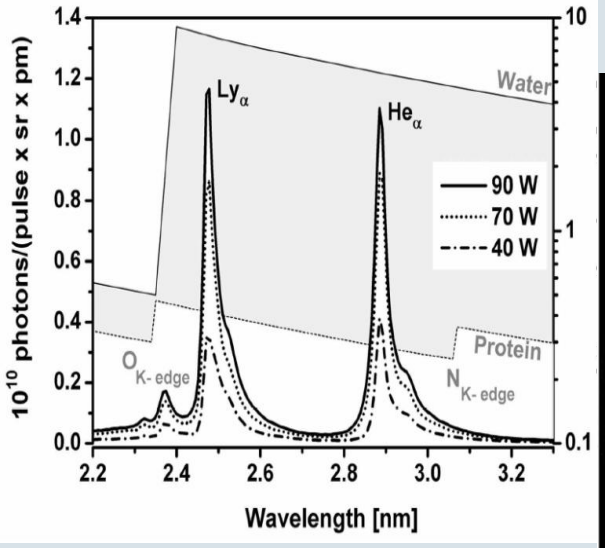
1000 x magnified diatoms and 80 nm latex spheres

M. Benk, K. Bergmann, D. Schäfer (2007, 2008)

Bruker ASC

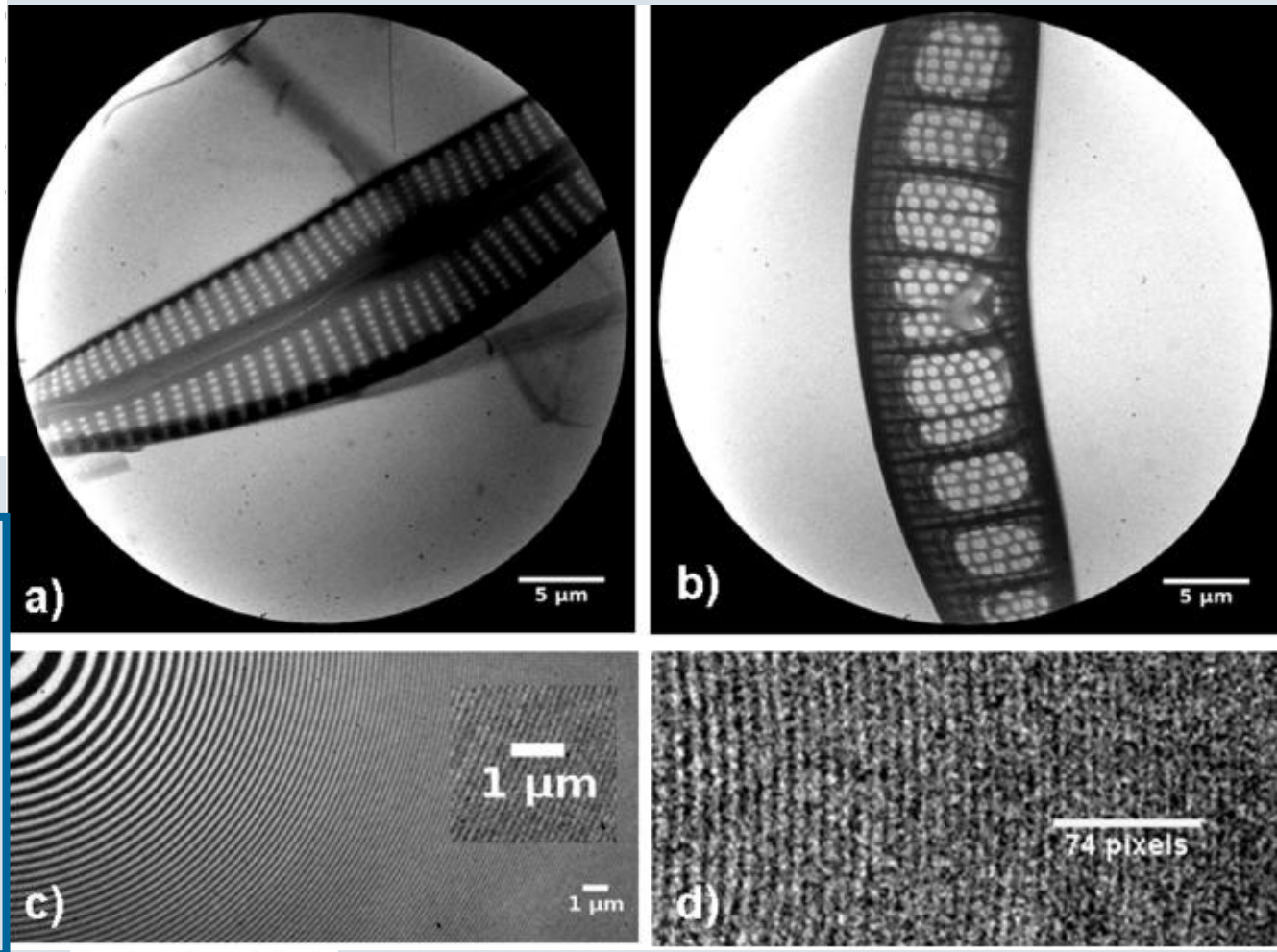
With LPP source

40 nm Rayleigh Resolution demonstrated



LPP Source

- < 90 W laser
- Single Line (≈ 0.1 % BW)
- 18*45 µm² source
- CE ≈: 0.4 % /(2 p sr)
  - ≈: 0.3 W /(2 p sr)
  - < 70 W/mm²/sr



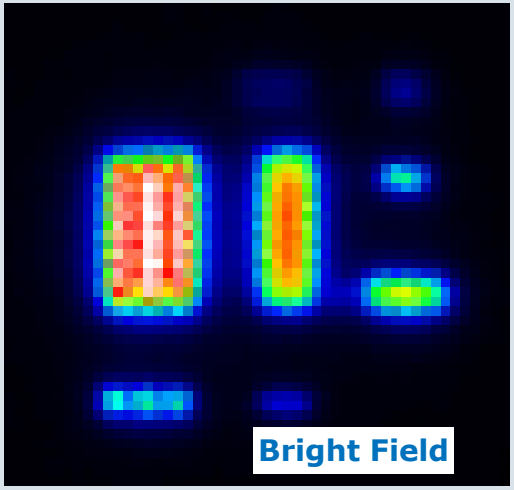
Compact x-ray microscope for the water window based on a high brightness laser plasma source

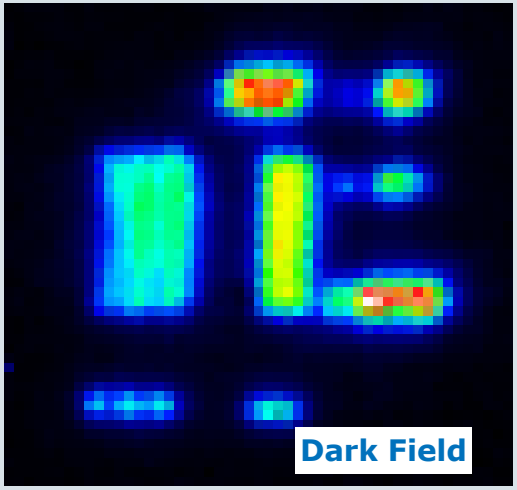
H. Legall,[1,2,*] G. Blobel,[1,2] H. Stiel,[1,2] W. Sandner,[1,3] C. Seim,[1,4] P. Takman,[5] D. H. Martz,[5] M. Selin,[5] U. Vogt,[5] H. M. Hertz,[5] D. Esser,[6] H. Sipma,[6] J. Luttmann,[6] M. Höfer,[6] H. D. Hoffmann,[6] S. Yulin,[7] T. Feigl,[7] S. Rehbein,[8] P. Guttmann,[8] G. Schneider,[8] U. Wiesemann,[9] M. Wirtz,[9] and W. Diete[9]

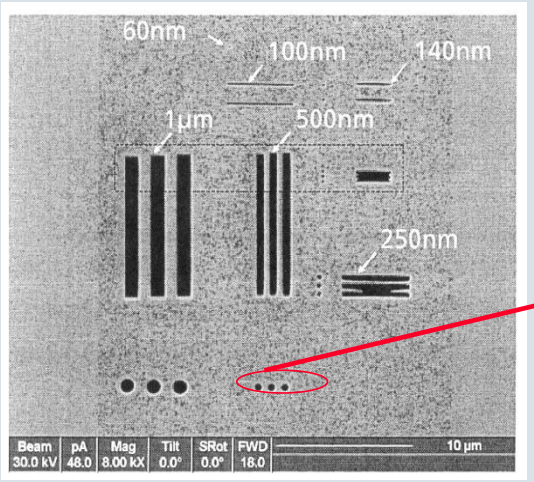
Fig. 5. Microscope images of diatoms and zone plate structures. The images (a)–(c) were taken with a pixel size of 26 nm, the image (d) with a pixel size of 13.5 nm. The exposure times were 2 min for image (a) and (b), 3 min for (c) and 1 min for image (d).

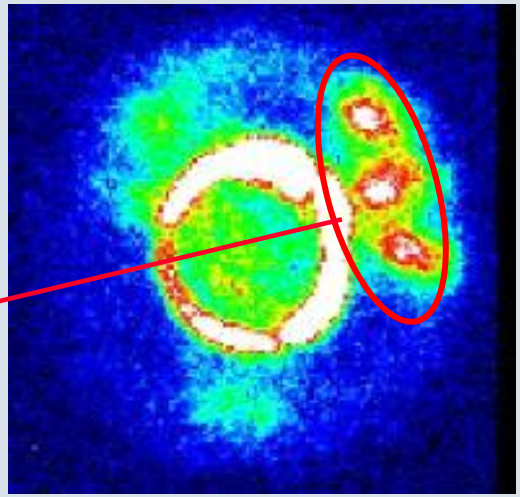
Bruker ASC

Actinic EUV Microscope with DPP EUV-Lamp









"Three Points" of transmission mask
dist = 100 nm, W = 100 nm, mag = 224

EUV Mask : Actinic Blank Defect Inspection
R&D Grade ABIT in Operation

Task

Find all defects of > x nm on mask blanks. Also purely actinic

Demands

- 100 µW irradiated on sample spot of 1*1 mm²
- Spectrally and flare clean irradiation

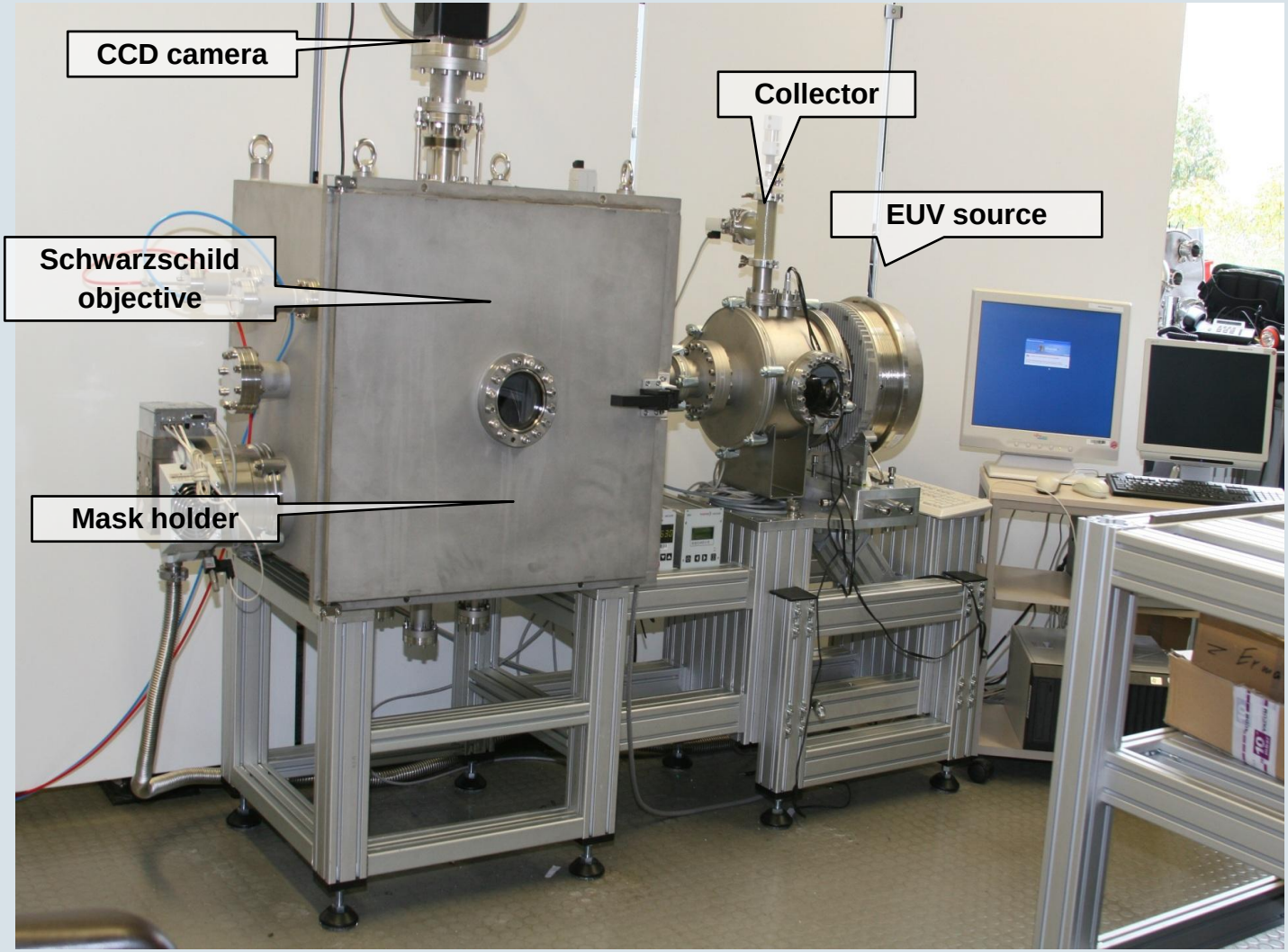
Concept & Source

Dark field microscope

DPP EUV-Source

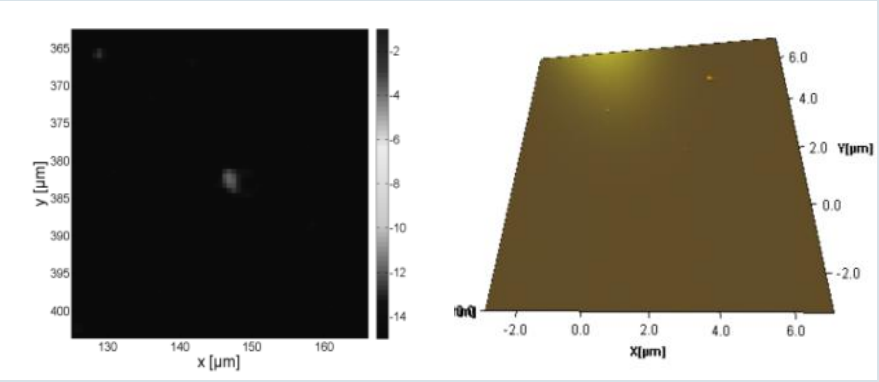
Filtered, magnified , homogen. irradiation

Large collection angle



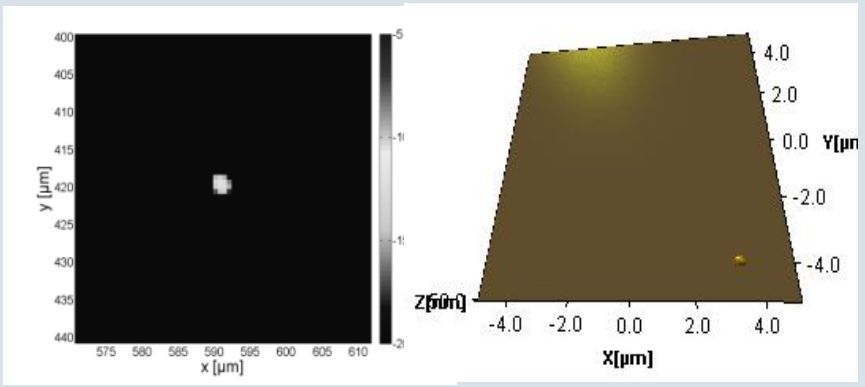
Investigation results:
Natural defects on a multilayer mirror

EUV **AFM**

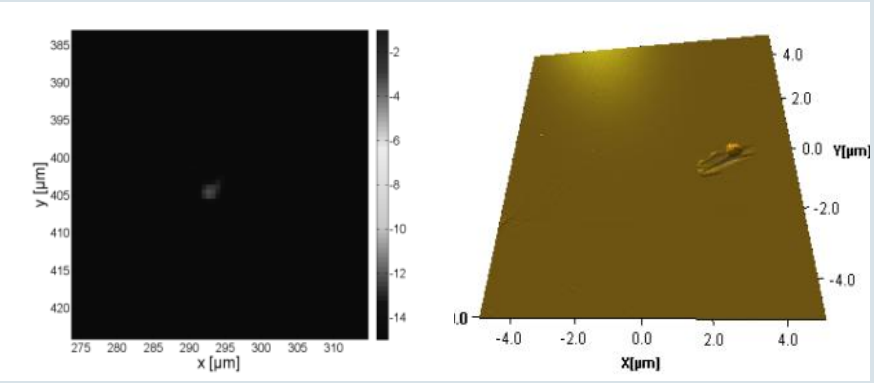


Bump:
Sphere: 220nm
Circle: 250 nm
Height: 160 nm

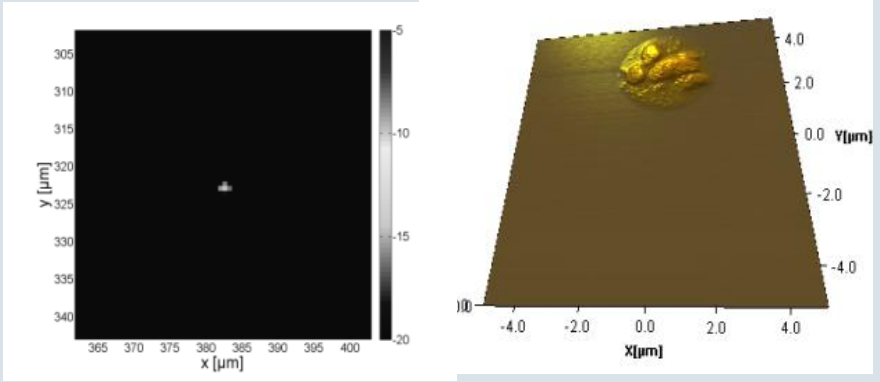
EUV **AFM**



Potential phase defect



Sphere: 81 nm
Circle: 133 nm
Height: 25 nm



Sphere: 720 nm
Circle: 1220 nm
Height: 210 nm

Actinic Scatterometry

Task

Quantify and Qualify flare due to scatter from roughness (actinic)

Demands:

Medium source power

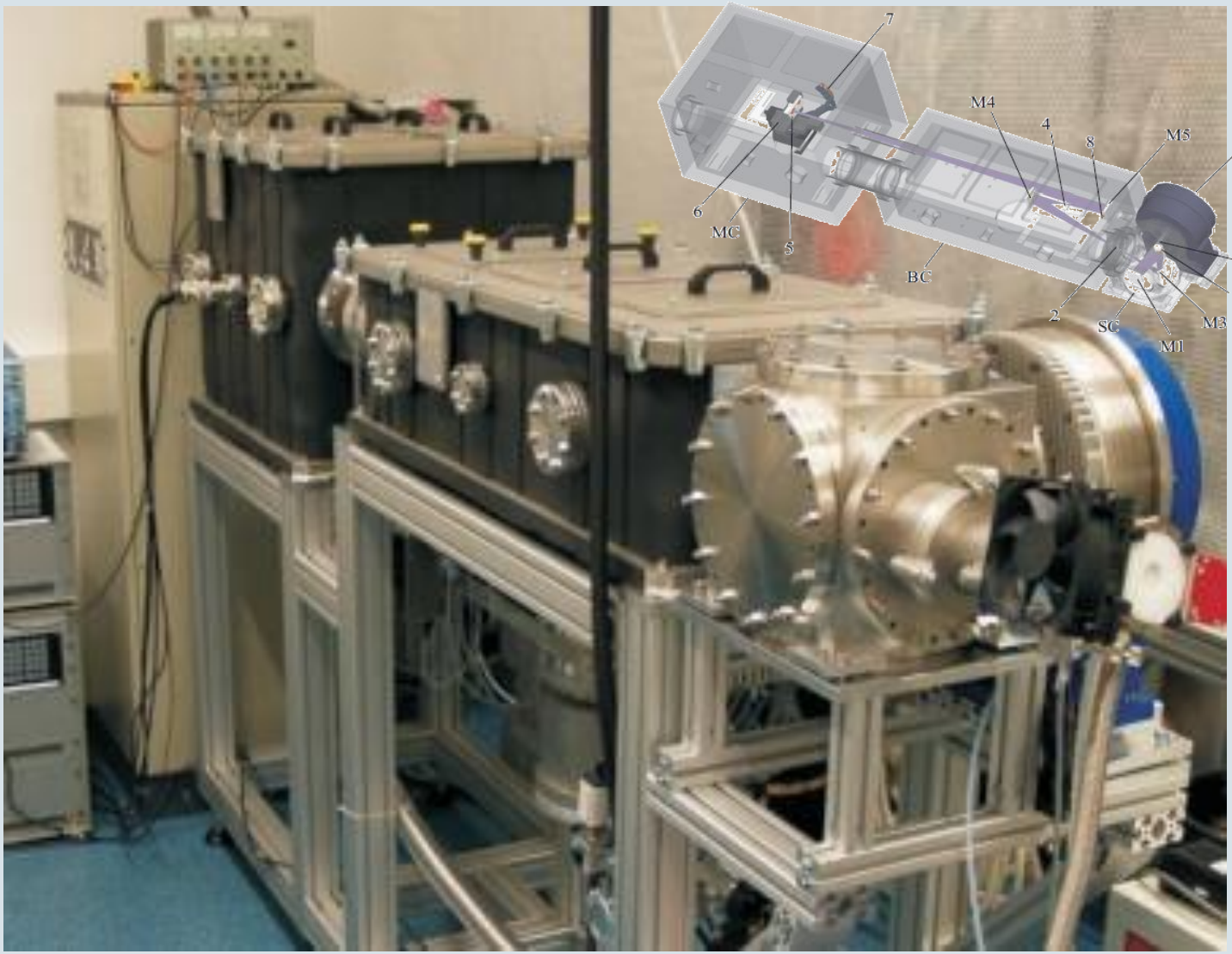
Spectrally and flare clean irradiation

Concept & Source

DPP Source

SPF+ML reflection for beam forming and cleaning

Beam Monitored

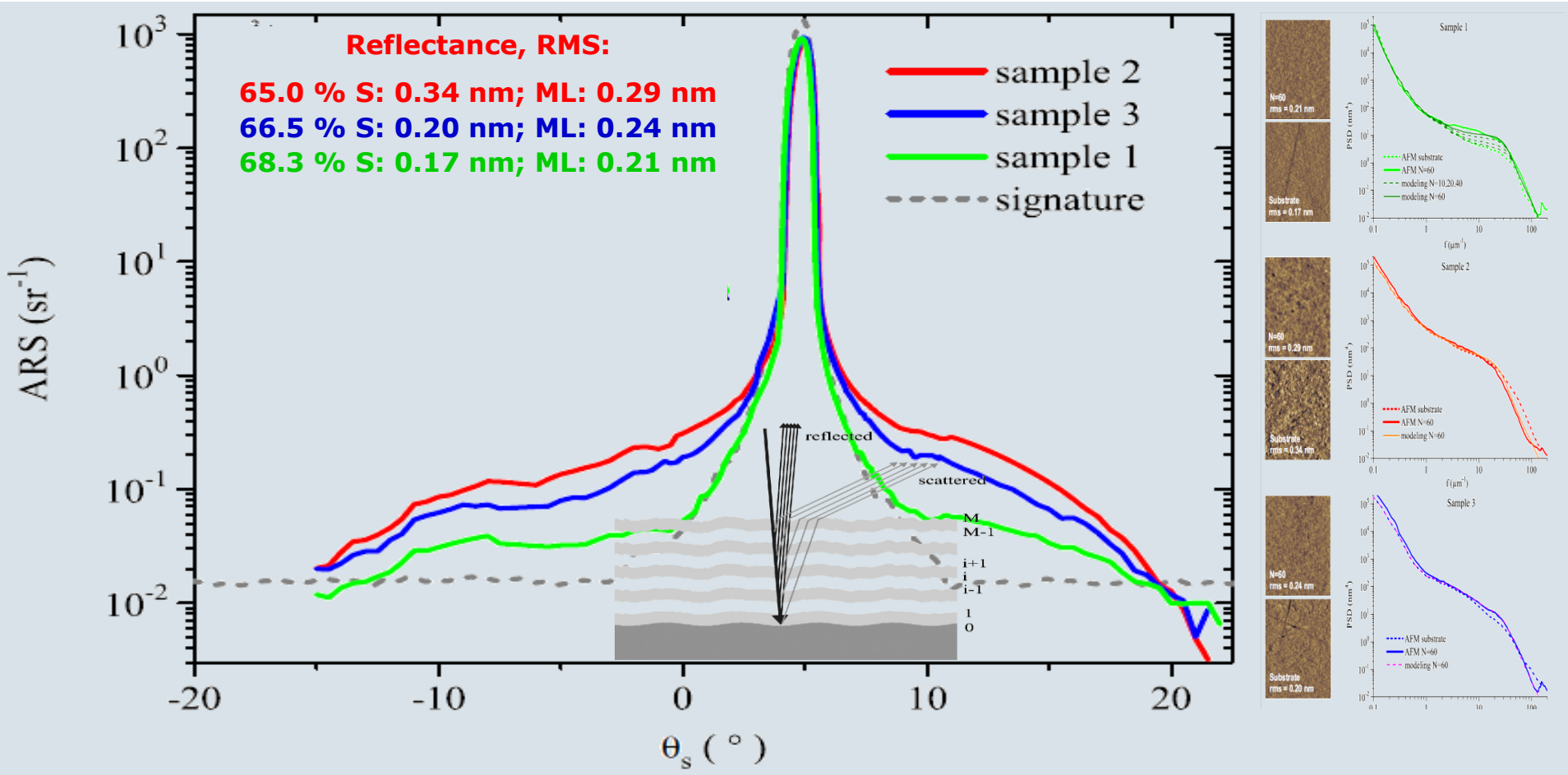


MERLIN
MEASUREMENT OF EUV REFLECTANCE AND SCATTERING

EUV reflectance and scattering of Mo/Si multilayers on differently polished substrates

Bruker ASC

Reflectance & angle resolved scatter



Peak Reflectance and Flare (Roughness) are relevant quality measures for EUV optics and mask blanks

With alternative concept, they can be scanned easily to additionally check for CWL quality (patented).

➔ Full, dense scan of quality area can be performed in <35 minutes with 1 mm² spots.

Concept demonstration CD-Metrology: Wide Angle XUV GI Scatterometry

Task

Collect Scatter information from structures for qualification of samples

Demands

Compromise:

Resolution, Wavelength, Angle of Incidence

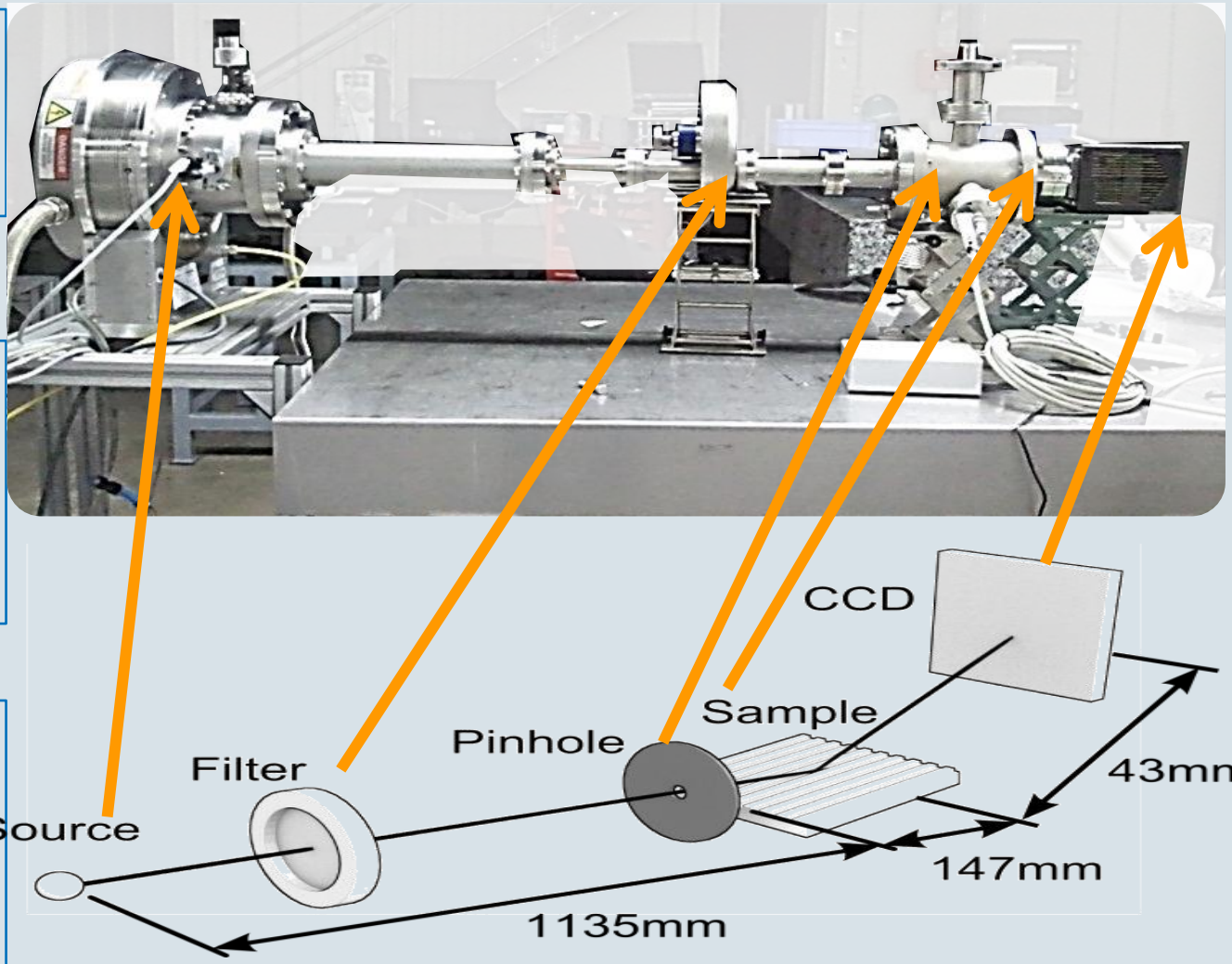
Monochromatic irradiation

Concept & Source

DPP or LPP source tuned and filtered for narrowband irradiation

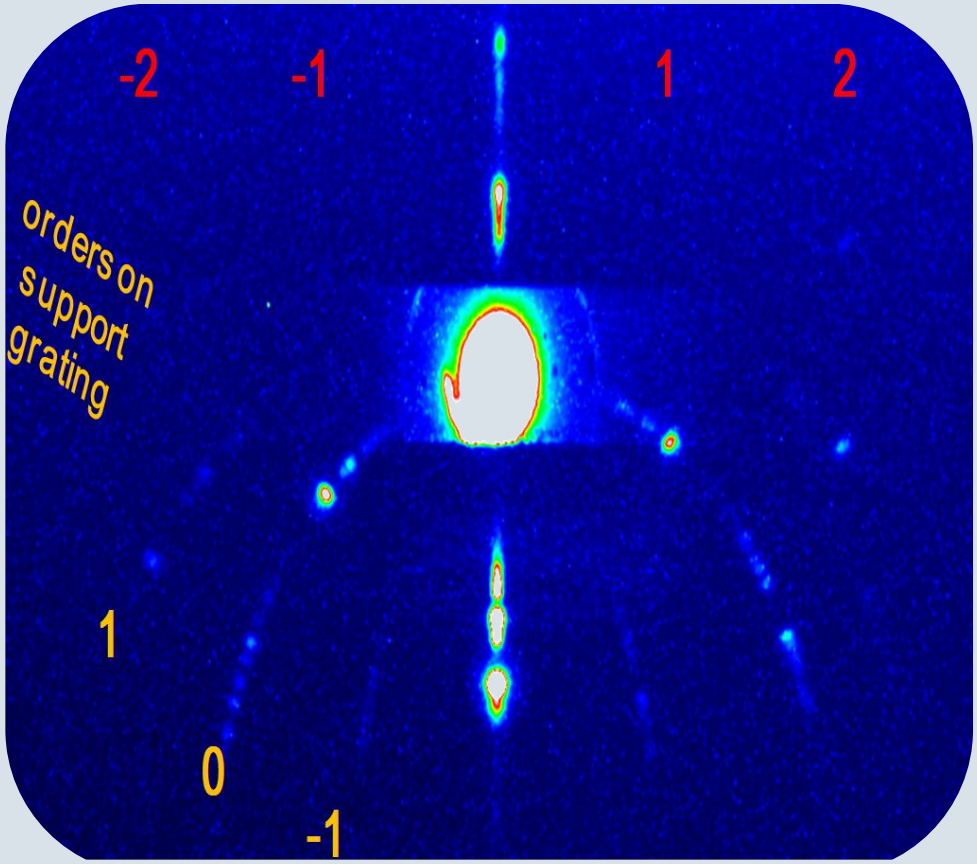
Clean collimated beam

Finite angles (> 5 °)

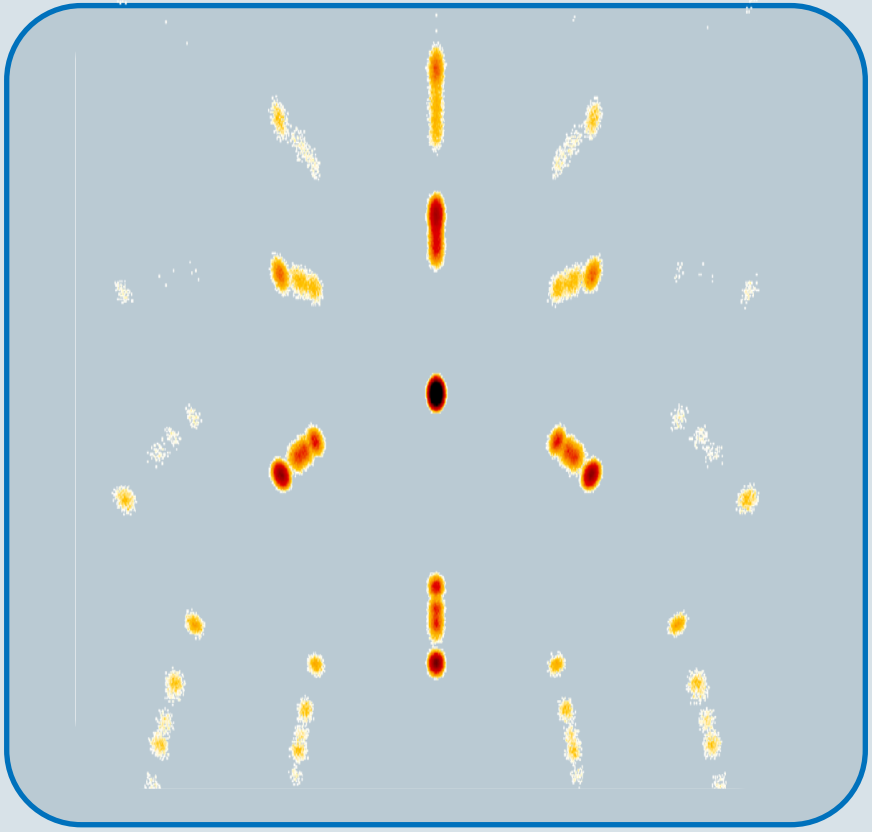


Straight forward compact Proof of feasibility experiment set-up with available lab components at BASC.

CD-WA-XUV-Scatterometry: First results



Typical Result obtained with PoP set-up



Simulation of expected result is in agreement

< 1mm² spot >5° AOI exp.< 10 s per image No beam stop

Spectral distribution exploits flexibility of EUV-Lamp with different working gases

➔ Achieved: Accuracy of CD < ± 2 nm Reproducibility. < 0.06 nm rms < 0.2 nm PV

Bruker ASC

Actinic CD on masks is straight forward solvable task. Demand ? Specs ?

Summary

BASC & Partners: Concepts, R&D and Supply of Solutions for the Industry

Path:

*** Concept Studies on most effective solution.**
*** Selecting from our flexible portfolio of sources**
*** Tailoring to the task**
+ Tailored optical concept
+ Select suited components from our partners and suppliers
+ Realize and integrate based on experiences: UHV, optics, mechanics, automation, control

Records:

We have realized tools and developed concepts to meet demands in EUVL ramp-up metrology and beyond in Mask Metrology, Resist testing, Nanoscopy, CD-Metrology, etc.

Services:

Customer tailored, adapted solutions for one of a kind realization is our business ! ➔
We are open to be confronted with demanding top level specs and study solutions and deliver case studies, test set-ups in our lab for PoC to full tool development and delivery.

Thank you for your attention

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